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RECOMMENDATIONS ON GUIDANCE FOR TECHNIC TO REDUCE UNNECESSARY EXPOSURE FROM X-RAY STUDIES IN FEDERAL HEALTH CARE FACILITIES

Environmental Protection Agency,
Washington, D. C.

June 1976

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RECOMMENDATIONS ON GUIDANCE FOR TECHNIC TO REDUCE UNNECESSARY EXPOSURE FROM X-RAY STUDIES IN FEDERAL HEALTH CARE FACILITIES

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The Administrator of the Environmental Protection Agency formed an Interagency Working Group on July 5, 1974, to develop guidance to reduce unnecessary radiation exposures from the use of x rays in the healing arts in Federal health care facilities. The consensus of this group was that is is desirable and possible to reduce exposure from diagnostic uses of x rays by: (1) eliminating clinically unproductive examinations, (2) assuring the use of optimal technic when examinations are performed, and (3) requiring appropriate equipment to be used. As a result of this consensus a Subcommittee was formed to examine the use of equipment and technic to perform medical and dental x-ray examinations and to make recommendations for guidance to assure that diagnostic quality radiographs are produced with minimal patient exposure. The recommendations made herein are believed to be basic to assuring that these considerations are met in Federal health care facilities.

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Report of

Subcommittee on Technic of Exposure Prevention

Interagency Working Group on Medical Radiation
U.S. Environmental Protection Agency
Washington, D.C. 20460

June 1976

PREFACE

The Administrator of the Environmental Protection Agency formed an Interagency Working Group on July 5, 1974, to develop guidance to reduce unnecessary radiation exposures from the use of x rays in the healing arts in Federal health care facilities. The consensus of this group was that it is desirable and possible in Federal facilities to reduce exposure from diagnostic uses of x rays by: 1) eliminating clinically unproductive examinations, 2) assuring the use of optimal technic when examinations are performed, and 3) requiring appropriate equipment to be used. As a result of this consensus a Subcommittee on Technic of Exposure Prevention was formed to examine the use of equipment and technic to perform medical and dental x-ray examinations and to make recommendations for guidance to assure that diagnostic quality radiographs are produced with minimal patient exposure. The recommendations made herein are believed to be basic to assuring that these considerations are met in Federal health care facilities.

A Subcommittee on Prescription of Exposure to X rays has examined considerations for eliminating clinically unproductive examinations. Its report, which was published in March 1976, and this report will form the basis for recommended Federal radiation guidance for the use of x rays in Federal health care facilities. This Subcommittee recognizes that the body of knowledge on both radiation exposure and technic for performing x-ray examinations is rapidly changing and the recommendations will, of necessity, need periodic review and appropriate revision.

James E. Martin, Ph.D.
Chairman, Subcommittee on
Technic of Exposure Prevention

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INTRODUCTION AND RECOMMENDATIONS

The fundamental objective of an x-ray examination is to obtain optimum diagnostic information with minimum patient exposure. The achievement of optimum diagnostic information with minimum exposure requires: 1) assurance that all equipment is functioning properly and calibrated as required; 2) operation of equipment is only by competent personnel; 3) the patient is appropriately prepared; and 4) technic factors which will minimize exposure are selected.

The Subcommittee on Technic of Exposure Prevention has considered each of the above areas to assure that good technic is employed in Federal health care facilities. The recommendations of this report address quality assurance, radiographic technic, operator qualifications, and exposure guidance. Because many details of good radiographic procedures depend on good judgment by qualified professionals, the recommended guidance is stated in the form of broad principles. Programs of the various Federal agencies continue to develop information and procedures that are expected to lead to optimal mechanisms of meeting these broad principles.

Within this framework, the following recommendations are made for guidance on technic for performing medical and dental radiographic procedures in fixed Federal and government owned contractor-operated health care facilities:

1. An equipment quality assurance program containing equipment specifications, equipment calibration requirements, materials and equipment performance requirements, and preventive maintenance schedules should be established in all Federal health care facilities.

2. The highest-speed film and film-screen combinations, which are consistent with image quality requirements, should be used.

3. Radiographic films should be stored, handled, and processed in appropriately equipped rooms. Periodic quality control inspections should be made for each aspect of film storage, handling, and processing that may affect radiographic quality or patient exposure.

4. The performance of diagnostic x-ray examinations should be in accordance with a procedural program which details patient preparation, use of technic charts, and quality control checks of finished radiographs to minimize retakes.

5. Operation of diagnostic medical x-ray equipment should be by individuals having adequate knowledge of radiation principles. These individuals should be qualified by a combination of didactic training and experience identical to or equivalent to the requirements of programs approved by either the council on Medical Education of the American Medical Association or the American Registry of Clinical Radiography Technologists.

6. Individuals performing radiographic examinations should select optimal technic and provide patients optimal preparation, instruction, and positioning; proper collimation and shielding should be used to restrict the x-ray beam as much as practicable to the clinical area of interest.

7. Facility protocol concerning examinations of pregnant or potentially pregnant patients should assure that medical consideration has been given to possible fetal exposure and appropriate protective measures are applied.

8. Appropriate area shielding should be used to limit gonadal exposure where such protection does not interfere with the objectives of the examination.

9. Exposures from routine diagnostic x-ray examinations should be periodically determined, the technic evaluated, and practicable measures undertaken to reduce exposures for those examinations which exceed the following Entrance Skin Exposure Guides (ESEG):

Examination (Projection)	ESEG (milliroentgens)*
Chest (P/A)	30
Skull (Lateral)	300
Abdomen (A/P)	750
Cervical Spine (A/P)	250
Thoracic Spine (A/P)	900
Full Spine (A/P)	300
Lumbo-Sacral Spine (A/P)	1000
Retrograde Pyelogram (A/P)	900
Feet (D/P)	270
Dental (Bitewing and Periapical)	700

*Entrance skin exposure for a reference patient selected by the NEXT program to have the following body part/thickness: head/15 cm, neck/13 cm, thorax/23 cm, abdomen/23 cm, and foot/8 cm.

10. Operation of diagnostic dental x-ray equipment should be by individuals having adequate knowledge of radiation protection principles. These individuals should be qualified by didactic training and experience programs consistent with the Guidelines for Dental Hygienist and Dental Assistant Training Programs in Dental Radiology adopted by the Oral Radiology Section of the American Association of Dental Schools.

11. Intra-oral radiography should be performed with open-ended, shielded, position-indicating devices with the x-ray beam as near the

size of the image receptor as practicable; other body tissues should be shielded from the direct beam and stray radiation.

12. The highest-speed film or image receptor of ANSI speed group rating of "D" or faster should be used for intra-oral radiography consistent with image quality requirements.

QUALITY ASSURANCE PROGRAMS

The production of consistent and high quality radiographs concurrent with minimal patient exposure depends on two important factors: quality performance of equipment and materials and optimal performance of the operator. Because of the complex interrelationship of equipment, technic, and procedural factors, each of which could affect radiographic quality and exposure, a functional quality assurance program to monitor the significant elements is desirable. Such a program is important to provide the diagnostician with consistent quality radiographs regardless of which operator or x-ray generator is involved in performing the examinations. At the same time such a program could minimize patient exposure and the number of retake examinations with an anticipated reduction in material, equipment, and personnel costs.

There is considerable recognition of the need for quality assurance programs in diagnostic radiology. A Subcommittee of the Food and Drug Administration's Medical Radiation Advisory Committee views the existing lack of quality assurance programs in hospitals and outpatient facilities as a major source of unnecessary patient exposure and radiographs of poor diagnostic quality (1).

The benefits of consistently high quality radiographs and increased production efficiency would in themselves seem to provide compelling support for implementation of quality assurance programs in Federal health care facilities. In addition, it appears that a substantial portion of costs associated with a quality assurance

program could be justified by savings of resources such as film, processing chemicals, and labor. Meeting the objectives of quality assurance requires periodic monitoring of equipment performance and standards of procedure. The design and scope of quality assurance programs are expected to vary. The program should be consistent with the clinical specialty and available resources.

Equipment and Materials

The quality performance of equipment and materials is determined by such factors as: 1) initial verification of equipment performance per specifications, 2) ongoing testing and calibrations of equipment, 3) periodic cleaning, adjustment, and preventive maintenance for equipment, and 4) verification of material performance. The level of emphasis of each will vary according to the needs of each Federal health care facility. Therefore, the details for implementing each of these factors should be established by the appropriate authority.

Quality assurance of equipment begins with assuring that upon completion of installation and calibration of newly purchased equipment, and prior to its clinical use, that it meets Federal regulations (3) and any additional performance requirements. Once equipment has been placed into service, periodic performance and preventive maintenance surveys should be conducted to provide prompt remedial action and continuing assurance of desired operation. It is important to monitor such parameters as x-ray tube potential, tube current, timer, beam quality, filtration, and focal spot size, especially when equipment is calibrated or receives preventive

maintenance (3,4,5). Another factor which often affects the optimum use of x-ray equipment is the beam alignment and beam-limiting device.

Because of the importance of equipment and materials in producing high quality radiographs, it is recommended that:

> An equipment quality assurance program containing equipment specifications, equipment calibration requirements, materials, and equipment performance requirements, and preventive maintenance schedules should be established in all Federal health care facilities.

The quality of the finished radiograph depends upon the condition of the film prior to its use; thus, it is desirable to evaluate periodically the quality of unused film. Considerations of time, cost, and traumatized patients associated with repeat exams also suggests the need for a program to ensure adequate evaluation and handling of films (6,7,8). All films should be handled and stored under carefully controlled light, temperature, humidity, and background radiation conditions so that fogging can be minimized (3,9,10). Use of "safe lights" to minimize film fogging requires the selection of appropriate filters for the particular wave length sensitivities of the films. Dark rooms should be appropriately designed and operated to eliminate light leaks.

A periodic review of film and film-screen combinations used and their performance is suggested to assure optimal high quality radiography with minimum patient exposure. Image receptors should be as sensitive as is practicable consistent with the requirements of examinations since the use of faster speed receptors generally reduce patient exposure (11,12,13). On the other hand, cursory acceptance of

advanced speed films or screens should not occur at the expense of compromising necessary diagnostic information.

It is apparent that patient exposures can vary significantly just on the basis of film/screen considerations. Image receptor combinations recommended in the summary report of the First Image Receptor Conference on Film-Screen Combinations can be used as a current guide in this regard (14). The image receptor combinations discussed in this report represent a recent consensus of an assembled group of radiology experts. For most cases, the typically preferred receptors ranged from par-speed film/par-speed screen to par-speed film/hi-speed screen combinations. Recent studies have shown that some of the newer film/screen combinations can achieve a reduction in exposure for the majority of diagnostic x-ray examinations by factors of two to four without a reduction in quality of the image (15,16). Reductions in exposure can be achieved with certain technic factors by the use of rare earth intensifying screens together with suitable films which match the light emission characteristics of the screens. On this basis, it is recommended that:

> The highest-speed film and film-screen combinations, which are consistent with image quality requirements, should be used.

The concurrent objectives of consistently high quality radiographs and minimized patient exposure also require quality film processing. Whether processing is accomplished manually or by machine, the quality of the equipment, materials, calibrations, housekeeping, and preventive maintenance are important.

Automatic processing machines can, with proper maintenance and monitoring, be used to obtain consistent high quality processing. Selection of processors should assure that the processing achieved provides an image commensurate with the level of resolution and consistency of the other components of the radiology system (7,17,18). A preventive maintenance protocol for automatic processors is particularly important because of the many moving parts susceptible to failure. The scheduled cleaning and maintenance recommendations of the equipment manufacturers or an equivalent should be followed.

The concentration and replenishment of chemical solutions, proper functioning of temperature, process speed, and other controllers are significant considerations of film processing equipment. One method of assuring quality of film processing is to use control films periodically, especially upon the introduction of new preparations of processing chemicals. Sensitometric strip techniques have been shown to be of value in monitoring the quality of film processing (3,19,20). On the basis of these considerations, it is recommended that:

> Radiographic films should be stored, handled, and processed in appropriately equipped rooms; periodic quality control inspections should be made for each aspect of film storage, handling, and processing that may affect radiographic quality or patient exposure.

Operational Procedures

Monitoring of operator performance is important to ensuring that high quality radiographs are produced with minimized patient exposure. Upon receipt of an examination request, the x-ray equipment operator determines a patient's measurements and, in accordance with facility protocol, selects the film-screen-grid combination, the kV, and the mAs. Some facilities have both single and three-phase x-ray generators

and use several film-screen-grid combinations. In such situations, an up-to-date technic chart which gives optimum values for each generator is especially important. The chart can be particularly important for unusual situations and when the usual operator is not available.

Reduction of the number of radiographic retakes is generally agreed to be important in eliminating unnecessary exposure. Common causes for retakes are patient motion, errors in exposure, collimation, or positioning. Values of reported retake rates have ranged from approximately two to ten percent (21,22,23,24,25). Some variation in retake rates is reflective of the medical specialty and whether the x-ray facility is in a clinic, hospital, or teaching facility. Every reasonable effort should be made to eliminate retake examinations.

Unnecessary duplicate examinations result in costs and patient exposure that should be eliminated. Use of examinations on file is basic to this concern. This consideration has been addressed in a large-scale pilot project to automate scheduling and file room functions (26).

Monitoring by qualified technologists of the final processed radiograph for diagnostic quality before the diagnostician views it appears to be of value in identifying problem areas. Prompt monitoring provides for timely repeat examinations with minimum inconvenience and anxiety to the patient and provides notice of poor performance of equipment or operators (27). The recording of information related to retakes (e.g., the examination, projection, reason, technologist, x-ray generator, etc.) can assist in determining patterns of retakes and in decreasing their frequency.

It is recommended that:

The performance of diagnostic x-ray examinations should be in accordance with a procedural program which details patient preparation, use of technic charts, and quality control checks of finished radiographs to minimize retakes.

EQUIPMENT OPERATOR PERFORMANCE

It is possible to obtain a range of radiographs considered diagnostically acceptable by most radiologists and have entrance skin exposure vary by a factor of six to ten because of the choice of the various technic factors (28,29,30). Because of the importance of operators in minimizing exposure they ought to be cognizant of those technic interrelationships which accomplish minimized exposure. Each patient should have confidence that equipment operators: 1) are adequately trained to produce a diagnostic quality radiograph, 2) know how to produce the prescribed radiograph with the lowest possible exposure, and 3) periodically demonstrate continuing occupational competence.

Operator Qualification

Available evidence indicates that x-ray technologists who are trained and credentialed (registered, licensed, or certified by a State or voluntary credentialing organization) more often produce radiographs with lower average patient exposures than nontrained or noncredentialed operators (29,31). Such results should not be unexpected since many noncredentialed operators have little or no formal training in anatomy, patient positioning, or radiation protection practices. The analyses of Nationwide Evaluation of X-ray Trends (NEXT) program (32) data and recent proficiency test results indicate that inadequately trained operators are likely to expose patients and themselves unnecessarily (29,33). Personnel responsible for patient preparation and positioning, selection of technic factors, radiation protection

measures, and film processing should be trained to produce quality radiographs. They should also be able to optimize various technic factors of the x-ray equipment to produce the radiograph at the lowest practicable patient exposure and to use optimal procedures in working with patients and ancillary equipment to reduce to a minimum the number of repeat examinations (11,28,34,35). Performance of x-ray examinations by untrained personnel does not appear justified except for unusual circumstances.

Operator competence is normally achieved through the successful completion of a professionally approved training program which provides both a didactic base and sufficient practical experience. Such competence should be developed in accordance with training programs identical to or equivalent to those approved by the Council on Medical Education of the American Medical Association or the American Registry of Clinical Radiography Technologists.

Even though both didactic and practical training are necessary, the primary criterion is for each operator to accomplish and maintain a capability to perform optimal examinations. The American Society of Radiologic Technologists has advocated such a criterion (36). Continuing competence and professional growth should be encouraged with specific opportunities to further the person's knowledge and skills through attendance at workshops and institutes.

A policy should be established by the responsibile authority which details: 1) who may operate diagnostic x-ray equipment and the supervision required, 2) the education-training and/or proficiency requirements for x-ray equipment operators, and 3) requirements for

continuing education and demonstration of proficiency. This policy should be reviewed periodically and revised as appropriate. It is recommended that:

> Operation of diagnostic medical x-ray equipment should be by individuals having adequate knowledge of radiation protection principles. These individuals should be qualified by a combination of didactic training and experience identical to or equivalent to the requirements of programs approved by either the Council on Medical Education of the American Medical Association or the American Registry of Clinical Radiography Technologists.

Operator Responsibility

The responsibility of operators in performing x-ray examinations should be discharged through adherence to prescribed protocol. The operator should not perform any examination which has not been prescribed by an authorized person. In performing an examination, he should prepare the patient on the basis of the requesting prescription and facility protocol. Patients should be attired suitably with all objects removed that might cause artifacts and be positioned properly. They should also be instructed when to hold their breath and on the position required in each view to prevent blurring of the radiograph due to motion.

Collimation of the x-ray beam and shielding of body areas not being examined minimizes unnecessary exposure. Regardless of all other technic considerations, the useful beam should be confined to the clinical area of interest (12,13,37,38). The beam size should be generally limited to the image receptor size or smaller. The operator has a responsibility to use shielding where appropriate and practicable

to further limit the exposure of body tissues (11,27,28,39,40). Therefore, it is recommended that:

> Individuals performing radiographic examinations should select optimal technic and provide patients optimal preparation, instruction, and positioning; proper collimation and shielding should be used to restrict the x-ray beam as much as practicable to the clinical area of interest.

Special effort should be made to protect the blood forming organs of children (38,41,42). Particular care should be exercised when a fetus may be irradiated. The determination of whether a female patient may be pregnant should be considered by the referring clinician when the x-ray examination is prescribed. In addition, the procedure followed by an x-ray facility should ascertain that such a consideration has been made prior to exposing the patient so that additional precautions may be taken. Such a procedure would provide a mechanism for the diagnostician to consult the referring clinician before conducting the examination or to alter the examination. If the examination could result in exposure of the fetus, operators have a responsibility to use shielding to minimize such exposure. Therefore, it is recommended that:

> Facility protocol concerning x-ray examinations of pregnant or potentially pregnant patients should assure that medical consideration has been given to possible fetal exposure and appropriate protective measures are applied.

Minimization of the Genetically Significant Dose (GSD) has been a major goal of radiological protection for many years in order to provide protection for future generations. In an effort to reduce the GSD to the population, the U.S. Food and Drug Administration, in

cooperation with its Medical Radiation Advisory Committee and the American College of Radiology, has developed a proposed guideline (21 CFR 1000, Subpart C) which recommends the use of gonadal protection for those procedures in which the gonads lie within or are in close proximity to the x-ray field and where their exclusion would not compromise the clinical objectives of the examination (43). Specially designed shields for males were field tested during the course of developing the proposed guidelines and were found to be a desirable action for minimizing the GSD. This consideration is particularly important for those examinations which result in gonadal exposure of persons of reproductive potential due to the increasing use of x-rays in medical care (12,13,37,38,41). On this basis, it is recommended that:

> Appropriate area shielding should be used to limit gonadal exposure where such protection does not interfere with the objectives of the examination.

PATIENT EXPOSURE CONSIDERATIONS

Production of a radiograph results in two determinants: the qualitative evaluation by the diagnostician of the required diagnostic quality of the radiograph and the amount of radiation exposure required to produce it. Each radiograph is evaluated for acceptable quality by a technologist or the diagnostician. An explicit evaluation of exposure is not usually made for each radiograph, although a change in radiographic quality generally provides an indication of exposure variation. A periodic evaluation of exposures in accordance with appropriate guidelines for routine examinations would appear to provide a mechanism to indicate levels above which good technic was probably not used and appropriate actions are warranted to reduce such exposures.

The development of exposure guides necessitates consideration of those technic factors which most affect the exposure. Data from the Nationwide Evaluation of X-ray Trends (NEXT) were used for this purpose as detailed in Appendix A. The NEXT data probably provide a representative profile of the practice of diagnostic radiology in the United States at the present time. These data reflect the myriad of combinations of x-ray generator types; high, medium, and slow films and screens; film processing technic; high, medium, and low contrast requirements of the diagnostician; and a range of skills of equipment operators. Therefore, regardless of the specific details or combinations of all these factors, the frequency distributions of entrance skin exposures (ESE) derived from the NEXT data are assumed to

be sufficiently representative of the complex system of diagnostician preference, operator technic, and x-ray equipment performance for the selected routine examinations.

The distributions of ESE from the NEXT data (Appendix A, Figures 1-12) are generally skewed to the high exposure side and at some point they begin to represent unnecessary exposure due to poor equipment or less than optimal technic factors. The choice of the point in the distribution where exposures become unnecessarily high is difficult since it is necessary to allow for a normal range of diagnostician preference and state-of-the-art variations in x-ray generating equipment, ancillary equipment, and technic factors. Careful consideration of these factors and the ESE data from the NEXT program suggests that exposures above the third quartile (i.e., those in the fourth quartile) probably represent unnecessary exposure. In order to determine whether exposures in the fourth quartile were unnecessary, the military services reviewed such surveys to determine whether adjustments in equipment and technic factors could be made to reduce the ESE below the fourth quartile without significantly affecting image quality. For these surveys, it was found that minor adjustments in technic could reasonably be made to reduce values of ESE below the fourth quartile.

There are several examples for the use of the third quartile as the level above which patient exposures could be considered excessive. In the consideration of the range of exposures utilized for chest examinations as represented by NEXT survey data, a Bureau of Radiological Health staff report noted that "exposures falling above

the third quartile can be considered as overexposures to patients" (29). The Illinois Division of Radiological Health, Department of Public Health, reasoned that if 75% of the existing facilities could obtain a clinically acceptable radiograph by exposing patients below that level, then the other 25% of facilities should be able to alter their technic to reduce unnecessarily high radiation exposure (44).

The decision that exposure guides should be at the third quartile of the NEXT data accommodates these considerations. It is important, however, to emphasize that good technic can be selected which will generally produce practicable levels of exposure well below these guides. For each type of x-ray examination there exists, within available technology, an optimal combination of type of x-ray generator, technic factors and ancillary equipment to produce a diagnostic radiograph at optimal exposure. Hence, it is important to evaluate each system to determine what exposure is as low as reasonably achievable and to establish procedures that routinely assure that exposures are consistently near that exposure level. Such determinations require an evaluation of the diagnostic requirements, generators, films, screens, technic factors, etc. of each facility. In certain instances, it may be reasonable to exceed the exposure guide for the purpose of specified diagnostic information. The decision to exceed a guide should be based on an evaluation that the need for additional diagnostic information justifies the exception.

It is emphasized that these proposed guides apply to exposures for routine or non-specialty examinations and their implementation could be done with a reasonable expenditure of resources without restricting the

diagnostician's preference for image receptor combinations and radiographic technic. On the basis of these considerations it is recommended that:

> Exposures from routine diagnostic x-ray examinations should be periodically determined, the technic evaluated, and practicable measures undertaken to reduce exposures for those examinations which exceed the following Entrance Skin Exposure Guides (ESEG):

Examination (Projection)	ESEG (milliroentgens)*
Chest (P/A)	30
Skull (Lateral)	300
Abdomen (A/P)	750
Cervical Spine (A/P)	250
Thoracic Spine (A/P)	900
Full Spine (A/P)	300
Lumbo-Sacral Spine (A/P)	1000
Retrograde Pyelogram (A/P)	900
Feet (D/P)	270
Dental (Bitewing and Periapical)	700

*Entrance skin exposure for a reference patient selected by the NEXT program to have the following body part/thickness: head/15 cm, neck/13 cm, thorax/23 cm, abdomen/23 cm, and foot/8 cm.

DENTAL CONSIDERATIONS

The basic objective of the use of radiation in dentistry is to obtain the optimal diagnostic yield with the minimum of exposure to the patient, dental personnel and the public (45,46). Therefore, the previous considerations of quality assurance, operator competence, and minimized patient exposure have the same applicability to diagnostic dental radiology. The significant use of radiographic procedures in dentistry warrants addressing elements of recommended practice specifically related to this profession.

Equipment Operator Qualification

The operator should receive the appropriate education and training in the areas of anatomy, physics, technic principles of radiographic exposure, radiation protection, radiographic positioning, and film processing that are relevant to dental radiography.

All training programs designed to qualify a person to perform radiographic procedures in dentistry should satisfy the Guidelines for Dental Hygienist and Dental Assistants Training Programs in Dental Radiography adopted by the Oral Radiology Section of the American Association of Dental Schools. These guidelines were developed to assure the protection of the public and improve the diagnostic yield of dental radiographs. Primary objectives of the guidelines are that "...upon completion of a dental radiology training program the dental hygienist and dental assistant should be able to:

1. Express and practice radiological health measures that are required by legal and/or ethical considerations,

2. Describe and demonstrate competency in theoretical considerations underlying radiation hygiene and radiological practice,

3. Expose, process, evaluate for quality, mount and file radiographic projections usually involved in dental practice,

4. Produce films with density, definition, contrast and other attributes of sufficient diagnostic value to the dentist" (47).

Therefore, it is recommended that:

> Operation of diagnostic dental x-ray equipment should be by individuals having adequate knowledge of radiation protection principles. These individuals should be qualified by didactic training and experience programs consistent with the Guidelines for Dental Hygienist and Dental Assistant Training Programs in Dental Radiology adopted by the Oral Radiology Section of the American Association of Dental Schools.

Technic

Technic is as important for producing quality dental radiographs as it is in general medical diagnostic radiology. Important aspects of dental technic for reducing patient exposure are the accurate positioning and the use of the smallest practicable x-ray beam to the clinical area of interest. Collimation for dental x-ray systems to limit the beam should be in accordance with the beam diameter at skin entrance requirement of the Federal Diagnostic X-ray Equipment Performance Standards [21 CFR 1020.31(f)]. Significant advances in exposure reduction have been shown by the use of open-ended, shielded, position-indicating devices (PID) and a number of voluntary standard-setting organizations have recommended their use (45,48,49,50). In 1968, the Council on Dental Research of the American Dental Association (ADA) developed a set of recommendations which includes the use of

open-ended shielded cones (51). The Department of Health, Education and Welfare has also recommended that dental practitioners should be encouraged through increased educational and training activities to adopt the paralleling, long-cone technic which uses the long open-ended shielded PID (52). Regardless of other technic considerations, the useful beam should be limited insofar as practicable to the clinical area of interest through the use of definitive beam collimation and body shields. Therefore, it is recommended that:

> Intra-oral radiography should be performed with open-ended, shielded, position-indicating devices with the x-ray beam as near the size of the image receptor as practicable; other body tissues should be shielded from the direct beam and stray radiation.

In addition to the essential considerations of collimation, the general recommendation to use the fastest speed image receptor consistent with diagnostic requirements is again most important and appropriate. In 1968 the Council on Dental Research (ADA) recommended that dental clinics "...use the fastest speed film available" and that they "...request film of ANSI group rating of "D" or faster" (51,52). On the basis of this finding and the resultant patient exposure reduction with adequate film quality, it is recommended that:

> The highest-speed film or image receptor of ANSI speed group rating of "D" or faster should be used for intra-oral radiography consistent with image quality requirements.

It is recognized that the technic and technology of dental radiography are continually evolving and that new methodologies will be refined to provide practicable alternatives to current ones. The desirability of limiting the x-ray beam size to that of the image

receptor has been accomplished only recently, for example, by rectangular collimation technic (53,54,55,56). Another approach which involves placing a new focused radiation source within the mouth to reduce patient exposure is being investigated at the National Institute of Dental Research (57). Therefore, recommendations for dental radiography will, of necessity, need periodic review and appropriate revision.

APPENDIX A

The purpose of this Appendix is to present the data considered in developing exposure guidelines. The exposure data were obtained from the Nationwide Evaluation of X-ray Trends (NEXT), a program of the Conference of Radiation Control Program Directors (32).

The NEXT surveys provide the most recent data on radiation exposures and the corresponding technic factors used for selected radiographic examinations. Table 1 contains a list of the radiographic projections currently being surveyed in the NEXT program and the number of surveys conducted by the 37 participating States (labeled "all states") for the period July 1, 1973 through June 30, 1975 and the military services (labeled "Federal") from July 1973 through December 1975. The number of "Federal" surveys is quite limited when compared to "all-states" surveys, but both groups of surveys exhibit similar technic factors and exposure value summary statistics as shown in Tables 2, 3, and 4. For this reason, the larger statistical base provided by the "all-states" survey data were used as representative of patient exposure from x-ray examinations in Federal facilities.

The summary data in Tables 2, 3, and 4 do not demonstrate a consistent statistically-firm pattern for these factors. The frequency distributions of entrance skin exposures (ESE) derived from the "all-states" NEXT data for each examination/projection are shown in Figures 1 through 12. The distributions of these data are generally skewed to the high exposure side probably because of the use of either faulty x-ray generators or less than optimal technic.

Table 1

Type and Number of Nationwide Evaluation of X-ray Trends (NEXT)
Radiographic Examination Surveys for "All-States"
(July 1, 1973 to June 30, 1975) and "Federal"
(July 1, 1973 to December 31, 1975)

Examination (Projection)	No. of Surveys "All-States"	No. of Surveys "Federal"
Chest (P/A)	1670	281
Skull (Lat)	136	49
Abdomen (A/P)	564	135
Retrograde Pyelogram (A/P)	122	20
Thoracic Spine (A/P)	51	13
Cervical Spine (A/P)	223	18
Lumbo-Sacral Spine (A/P)	695	97
Full Spine (A/P)	47	3
Feet (D/P)	66	13
Bitewing Dental	1752	138
Periapical Dental	1055	115
Cephalometric Dental	35	0

TABLE 2. SUMMARY OF kVp FACTORS FOR NEXT SURVEYS

Type of Examination	"All-States" Surveys				"Federal" Surveys			
	No. of Surveys	kVp VALUES Mean	Low	High	No. of Surveys	kVp VALUES Mean	Low	High
Chest (P/A)	1667*	80	40	150	281	83	40	140
Skull (Lateral)	136	72	48	94	49	73	58	92
Abdomen (A/P)	564	78	45	125	135	83	58	110
Retrograde Pyelogram	122	77	55	106	20	72	58	82
Thoracic Spine (A/P)	51	75	57	90	13	80	68	92
Cervical Spine (A/P)	223	69	40	100	18	71	60	80
Lumbo-Sacral Spine (A/P)	695	77	55	106	97	79	62	100
Full Spine (A/P)	47	79	64	96	3	76	72	80
Feet (D/P)	59*	61	45	90	13	58	50	72
Dental (Bitewing)	1750*	71	40	110	138	84	60	100
Dental (Periapical)	1054*	71	40	110	115	83	43	100
Dental (Cephalometric)	35	81	60	98	0	0	0	0

*The number of surveys differs from number of surveys given in Table 1, due to omission of kVp entry in survey data.

TABLE 3. SUMMARY OF mAs FACTORS FOR NEXT SURVEYS

Type of Examination	"All-States" Surveys				"Federal" Surveys			
	No. of Surveys	mAs VALUES Mean	Low	High	No. of Surveys	mAs VALUES Mean	Low	High
Chest (P/A)	1670	12	2	100	281	12	1	100
Skull (Lateral)	136	50	5	150	49	60	25	150
Abdomen (A/P)	564	85	2	300	135	87	2	200
Retrograde Pyelograms	122	91	6	300	20	122	20	240
Thoracic Spine (A/P)	51	82	12	200	13	91	30	160
Cervical Spine (A/P)	223	48	2	200	18	33	20	60
Lumbo-Sacral Spine (A/P)	695	112	15	450	97	100	25	200
Full Spine (A/P)	47	173	20	400	3	97	90	100
Feet (D/P)	66	18	1	80	13	66	2	150
Dental (Bitewing)	1752	7	1	54	138	6	1	30
Dental (Periapical)	1055	7	1	75	115	7	1	105
Dental (Cephalometric)	35	18	3	60	0	0	0	0

TABLE 4. SUMMARY OF ESE FACTORS FOR NEXT SURVEYS

Type of Examination	"All-States" Surveys				"Federal" Surveys			
	No. of Surveys	ESE VALUES[1] Mean	Low	High	No. of Surveys	ESE VALUES[1] Mean	Low	High
Chest (P/A)	1670	24	2	266	281	33	3	369
Skull (Lateral)	136	291	28	2730	49	337	39	2821
Abdomen (A/P)	564	601	22	2222	135	659	4	2471
Retrograde Pyelogram	122	673	78	2200	20	558	62	1131
Thoracic Spine (A/P)	51	646	60	1737	13	746	67	1572
Cervical Spine (A/P)	223	206	13	1099	18	144	32	319
Lumbo-Sacral Spine (A/P)	695	787	41	5372	97	777	40	5544
Full Spine (A/P)	46	275	70	1417	3	495	331	653
Feet (D/P)	66	275	28	2676	13	128	2	470
Dental (Bitewing)	1752	579	62	6771	138	354	15	2258
Dental (Periapical)	1055	588	51	7559	115	330	15	2345
Dental (Cephalometric)	35	44	7	138	0	0	0	0

[1]Entrance Skin Exposure (ESE) in milliroentgens.

FIGURE 1 CHEST (P/A) 1670 SURVEYS

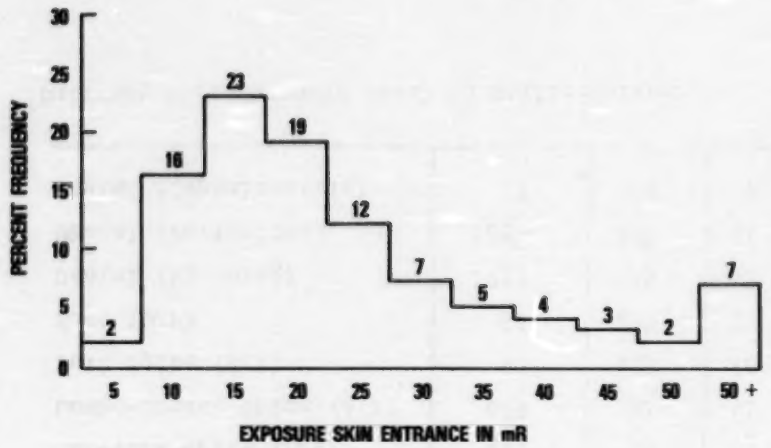


FIGURE 2 SKULL (LAT.) 136 SURVEYS

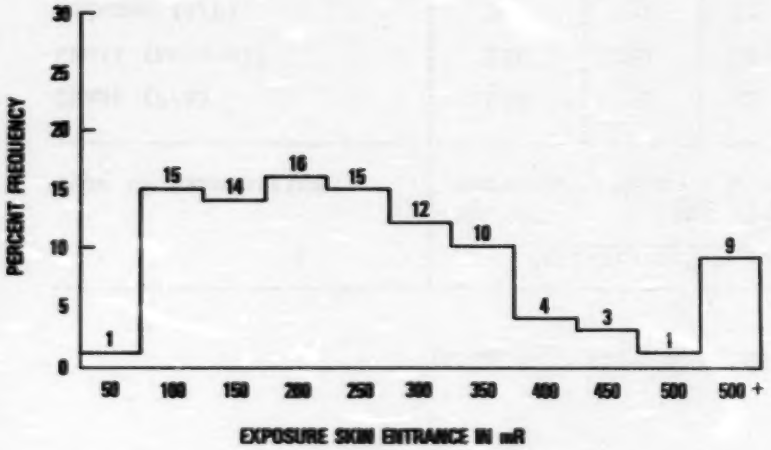


FIGURE 3 ABDOMEN (A/P) 564 SURVEYS

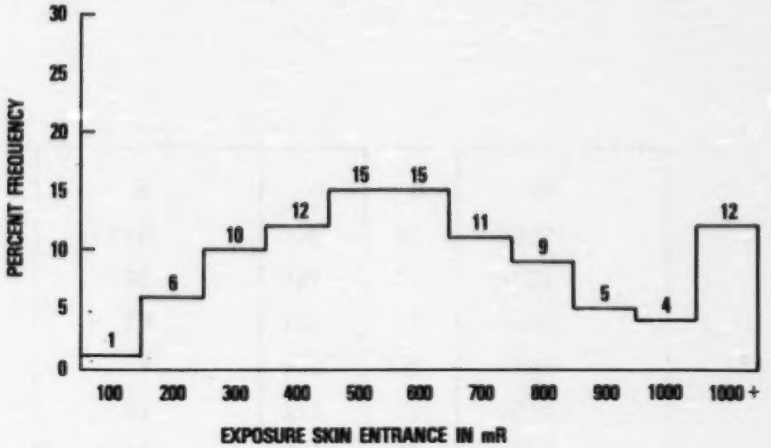


FIGURE 4 RETROGRADE PYELOGRAM
122 SURVEYS

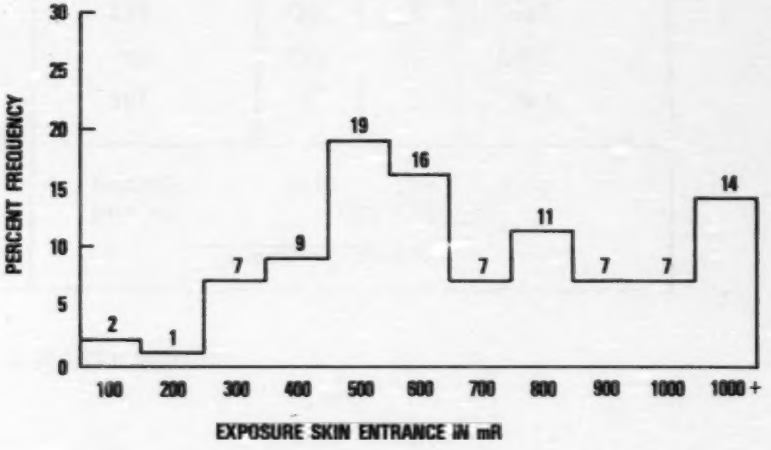


FIGURE 5 THORACIC SPINE (A/P) 51 SURVEYS

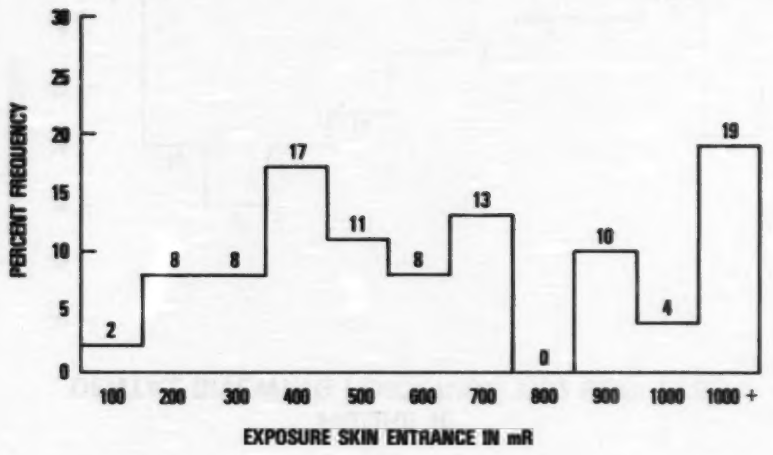


FIGURE 6 CERVICAL SPINE (A/P) 223 SURVEYS

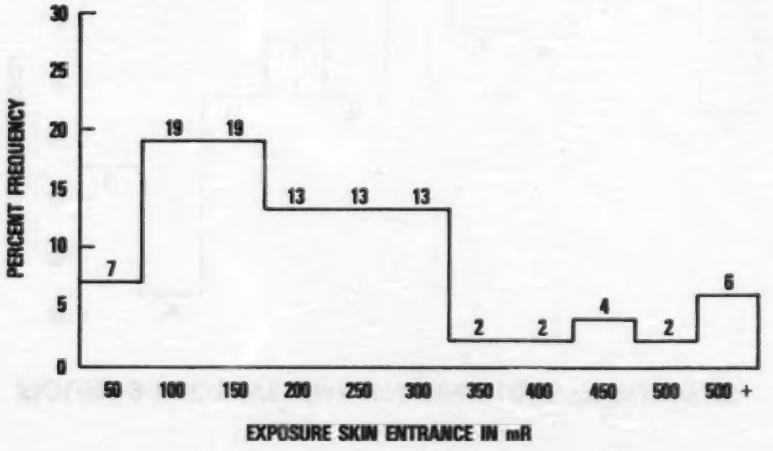


FIGURE 7 LUMBO-SACRAL SPINE (A/P) 695 SURVEYS

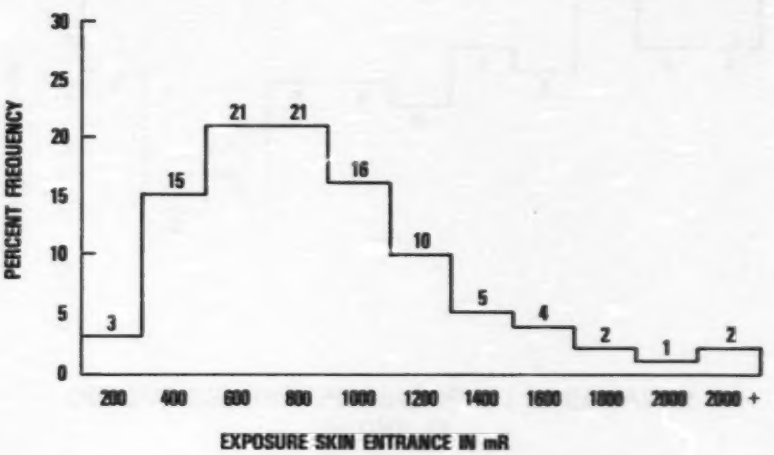


FIGURE 8 FULL SPINE (A/P) 47 SURVEYS

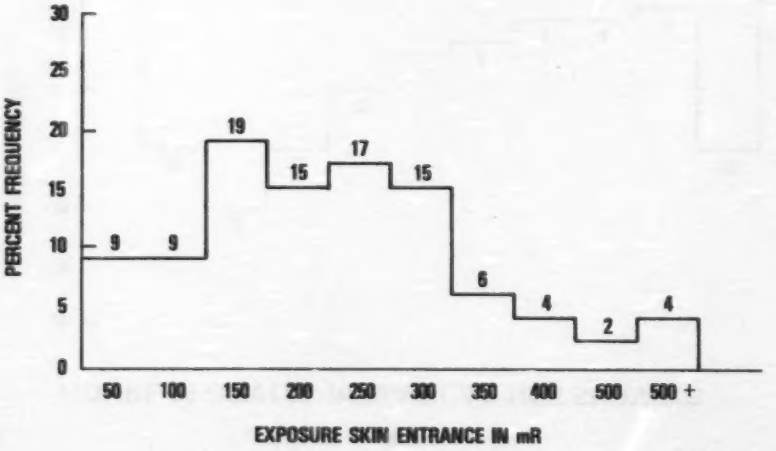


FIGURE 9 FOOT WEIGHT BEARING (D/P) 66 SURVEYS

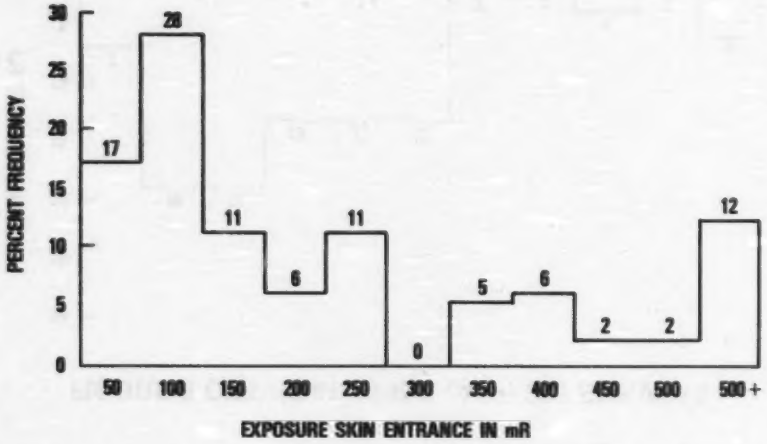


FIGURE 10
DENTAL BITEWING POSTERIOR 1752 SURVEYS

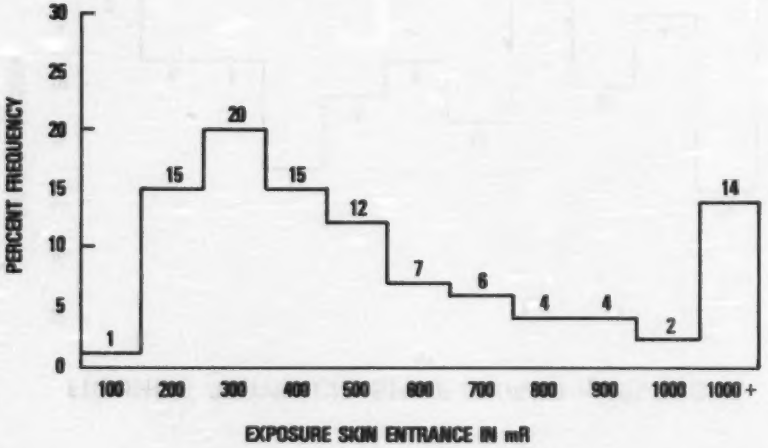


FIGURE 11 DENTAL PERIAPICAL 1055 SURVEYS

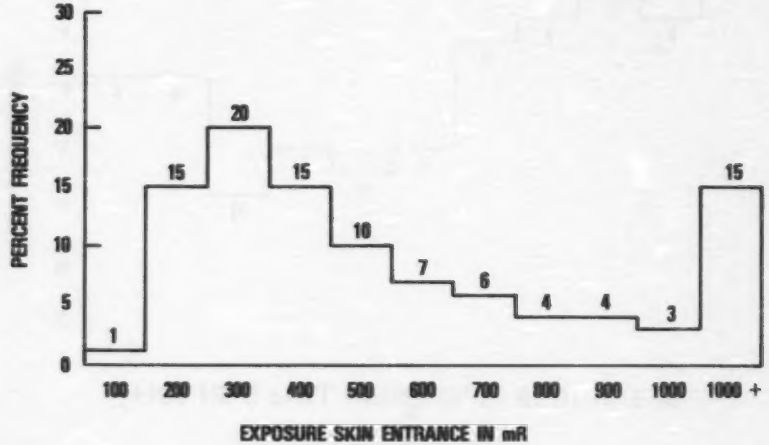
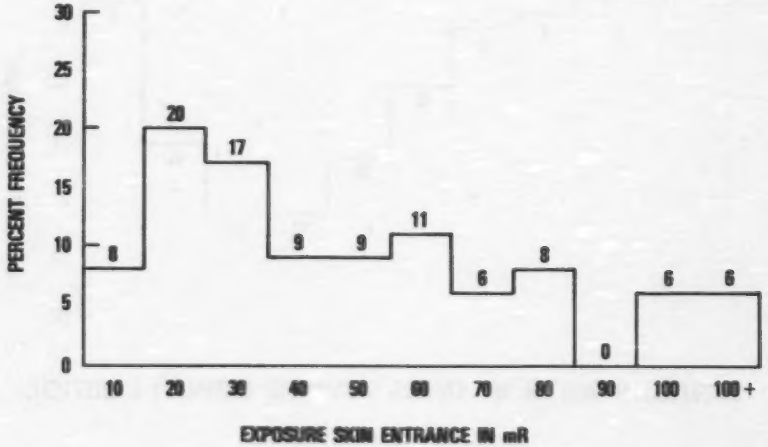


FIGURE 12
DENTAL CEPHALOMETRIC (LAT.) 35 SURVEYS



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